Research and Development Technical Report

ECOM-4473

RELIABILITY / COST ANALYSIS OF SINCGARS-V RADIO SERIES

John P. Solomond

Reliability / Maintainability Division
Product Assurance Directorate

February 1977

DISTRIBUTION STATEMENT
Approved for public release;
distribution unlimited.

ECOM

US ARMY ELECTRONICS COMMAND FORT MONMOUTH NEW JERSEY 07703

NOTICES

Disclaimers

Disposition

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ECOM-4473	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RELIABILITY/COST ANALYSIS OF SINCGARS-V RADIO SERIES		5. TYPE OF REPORT & PERIOD COVERED Research and development Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) JOHN P. SOLOMOND		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Advanced Methodology Branch Reliability/Maintainability Division Product Assurance Directorate USAECOM, Fort Monmouth, NJ 07703		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1X763707 D437 02
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Command ATTN: DRSEL-PA-RAM Fort Monmouth, NJ 07703		12. REPORT DATE Feb[redacted] [redacted]77
		13. NUMBER OF PAGES 38
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Prepared under funding provided by Project Manager SINCGARS (Single Channel Ground and Airborne Radio Systems)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

COST MODEL
RELIABILITY GROWTH
VHF-FM
COST OPTIMIZING SYSTEM TO EVALUATE RELIABILITY (COSTER)
MANPACK SUBSYSTEM
AIRBORNE SUBSYSTEM
VEHICULAR SUBSYSTEM

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The SINCGARS-V radio series consists of a VHF-FM radio system, electronically tuned and controlled, which operates in the 30 to 88 MHz frequency band. Three basic subsystems are analyzed on the basis of the specified reliability (design goal) and the cost incurred in order to obtain that reliability level.

The analysis contained herein elaborates the reliability program costs, expected field support costs, and the resultant MTBF achieved in the field.

Also included is an analysis of projected reliability growth efforts, including curves, during the advanced development, and engineering development over

(CONTINUED)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (CONTINUED)

phases of the equipment's life cycle; it includes a calculation of the expected reliability growth costs for each of the three subsystems, at several reliability growth rates.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

It was requested that quantitative rationale be developed for particular reliability specification values for each subsystem of the SINCGARS V radio series. The analysis was performed using the Cost Optimizing System To Evaluate Reliability (COSTER), a computerized cost model which weighs the effects of reliability changes on an equipment's overall field support cost as well as considering the cost of imposing particular reliability efforts during the equipment's advanced development, engineering development, and production phase of its life cycle.

COSTER calculates the cost, and reliability improvement subsequent to four major efforts, the reliability design and prediction tasks, reliability growth testing, demonstration-qualification-production sampling testing, and burn-in testing. Subsequent to reliability growth testing, any equipment failures are assumed to occur randomly, in accordance with an exponential distribution of time to failure. Consequently, the failure rate experienced upon field deployment is constant, and inversely related to the system's mean time between failure (MTBF). Likewise, the total expected field support cost is inversely related to the system's MTBF.

COSTER does not consider the fixed cost of research and development, since that is a sunk cost and will not impact upon the optimal reliability program.

ASSUMPTIONS

Each subsystem was assumed to have a 12 year expected usage life and operate approximately 21 hours per week, 52 weeks per year. The expected total field support costs are directly proportional to the expected operating time.

The total procurement quantities, and average repair costs for a failure experienced in the field are listed below for each subsystem.

SUBSYSTEM	QUANTITY PROCURED	UNIT REPAIR COST
Manpack	78,000	600
Vehicular	110,000	600
Airborne	12,000	800

These figures are based on generally accepted overhead and labor costs for general support, and direct support repair activities.

Prior to any reliability growth testing during advanced development, each radio system MANPACK, VEHICULAR, and AIRBORNE, will have undergone basic design analyses, reliability predictions, and environmental testing in accordance with MIL-STD-810C.

USER REQUIREMENTS

The minimum acceptable user requirements for the SINCGARS-V radio series are contained in the Army Signal School letter entitled: Proposed SINCGARS-V Operational Reliability Requirements, dated 6 August 1976. The operational mode summary for the SINCGARS-V series in Europe II provides typical mission profiles in a non-nuclear environment as part of a 2-1/3 Division Corps Force with a defend/delay mission against a numerically superior enemy force. The task-face is required to engage the tank-heavy enemy force in close and continuous combat for 84 to 96 hours. The communication response requires that the task force react to the Division and Brigade command and control as orders directing rapid lateral movement, coordinated for supporting fires and critical logistical support, are issued. Throughout the tactical engagement, the task force is required to maintain constant communication with its parent/brigade, adjacent maneuver battalion and the organization providing supporting fires. The 84-96 hour mission duration also represents a mission requirement for the Army aviation elements as part of the combined arms team.

Table 1 contains the Minimum acceptable user requirements in order to operate under such a scenario.

TABLE 1 USER MISSION MINIMUM ACCEPTABLE VALUE OF MTBF (HRS)

SUBSYSTEM(S)	USER MISSION MTBF (MAV) HRS			
	Basic Radio	With ECCM (1)	With COMSEC (2)	With ECCM & COMSEC (1, 2)
1. Manpack	1300	950	950	746
2. Vehicular (long range)	1250	920	920	730
3. Vehicular (long range) with separate receive only capability	1250	920	920	730
4. Aircraft	750	617	617	525

Note 1: ECCM = 3500 hours

Note 2: COMSEC = 3500 hours

The block diagrams are given in figure 1, for each radio subsystem.

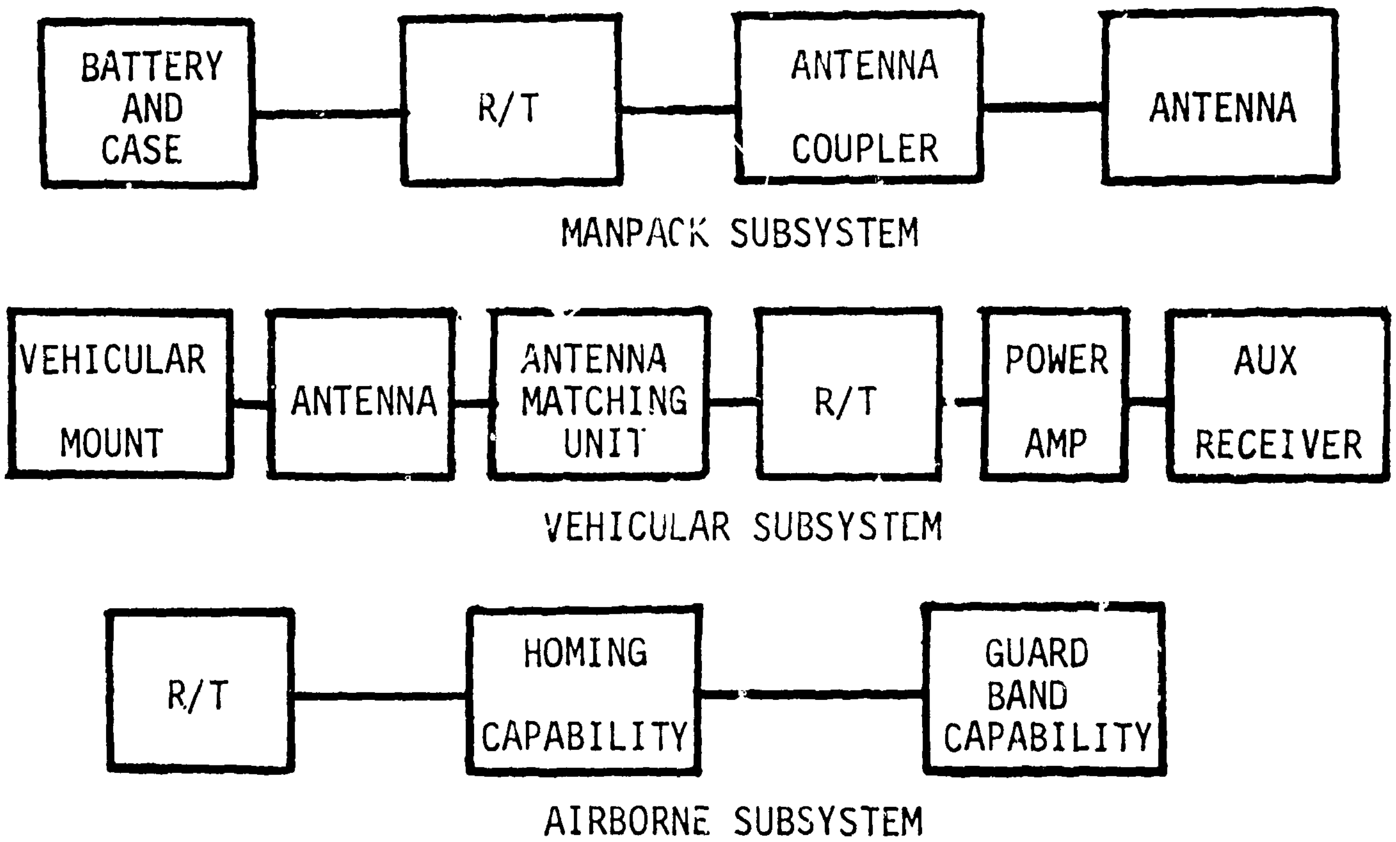


Figure 1 Block Diagrams for Each SINCGARS-V Subsystem

SYSTEM RELIABILITY GROWTH METHODOLOGY

Failures of a transceiver during a prescribed communication mission can be classified into two types, either they are inherent failures, or assignable cause failures. Each type may occur during a mission; hence, the failure occurrences are chance events.

Inherent failures are those whose assignable causes cannot be determined, and are due to the interaction of the system and the environment at the time of the impending failure. Inherent failures cannot be eliminated by a design change. Assignable cause failures are those which can be eliminated by a design change or by some other means. This may involve part substitution with more stringently screened parts, tighter quality control procedures, tolerance changes or other design changes. The important distinction between this type of failure and an inherent failure is that a definite assignable cause has been established and its future occurrence can be effectively prevented. It should be noted, however, that the occurrence of such assignable cause failures during a given mission is nevertheless due to chance - in that a combination of environment and other circumstances brings about the failure.

During reliability growth testing, "test-locate-fix" sequences will systematically eliminate assignable cause failures. It is assumed, however, that no new failures are introduced in making the necessary design or procedural changes. Figure 2 contains a schematic illustration of the growth of an equipment's reliability function.

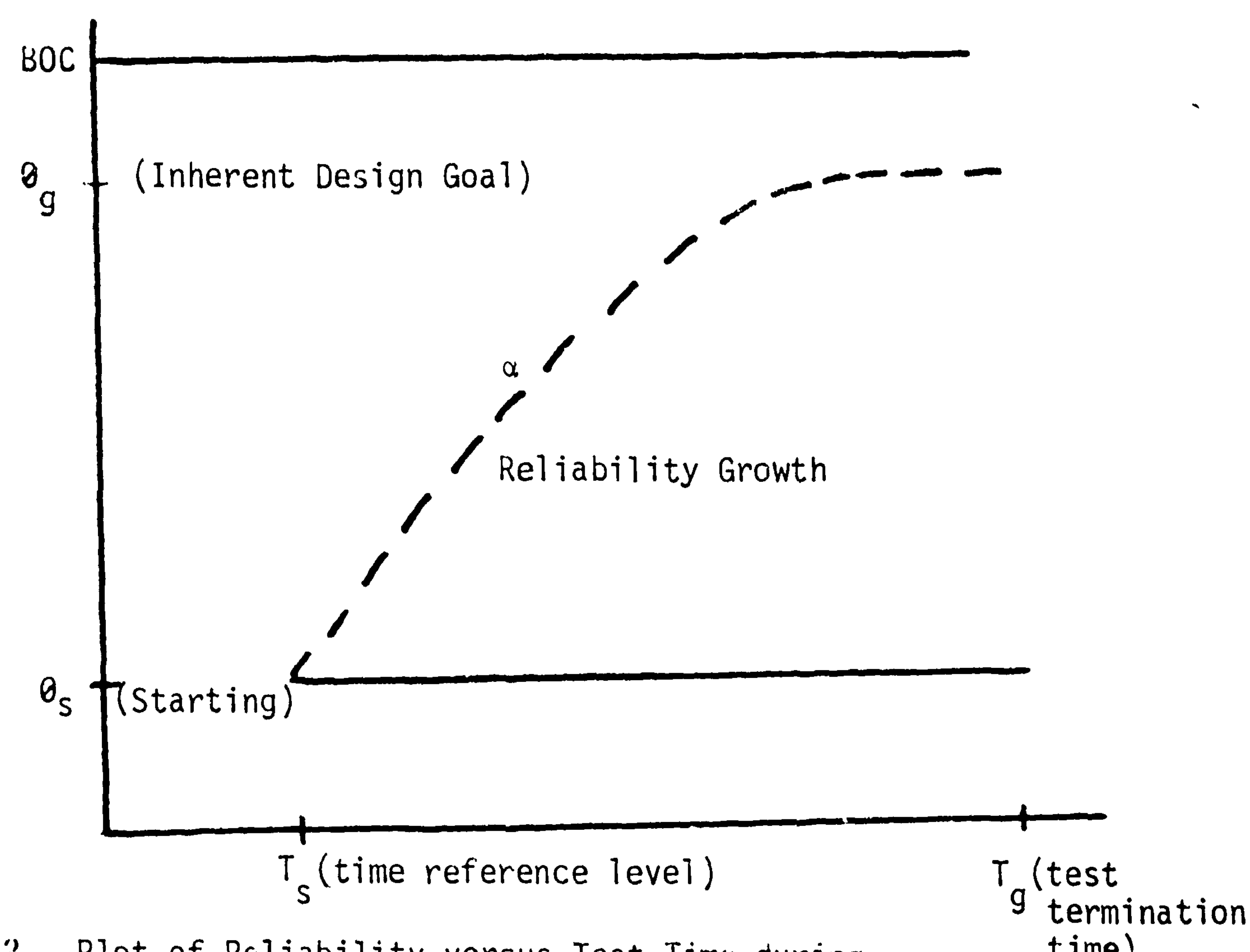


Figure 2. Plot of Reliability versus Test Time during Reliability Growth Testing

Duane (1) found that a plot of system MTBF versus cumulative test time yielded a straight line when plotted on log-log paper. Thus an appropriate analytical form for the reliability, expressed as the system MTBF, versus the reliability growth test time is

$\theta_c(T) = T^{\alpha}/K$, where

$\theta_c(T)$ is the cumulative MTBF after T hours of reliability growth testing,

α is the reliability growth rate, and

K is a proportionality constant usually determined by the MTBF after 100 hours of testing,

$K = 100^{\alpha}/R(100)$.

With a design goal of θ_g, after T_g hours of growth testing, and a starting MTBF of θ_s after T_s hours, the reliability growth rate is calculated as follows:

$$\alpha = \frac{\log \theta_g - \log \theta_s}{\log T_g - \log T_s}$$

Using common logarithms, and an initial test time of 100 hours, the formula for the growth rate becomes:

$$\alpha = \frac{\log \theta_g - \log \theta_s}{\log T_g - 2}$$

The instantaneous MTBF is calculated by dividing the cumulative values by $(1-\alpha)$:

$\theta_I(T) = \theta_c(T)/(1-\alpha)$

Figures 3 through 5 contain the projected reliability growth curves for each of the three radio subsystems.

The MANPACK Subsystem (Figure 3) has an instantaneous starting MTBF of 1117 hours after 100 hours of reliability growth testing and reaches an instantaneous MTBF of 4062 hours at the end of advanced development (AD), and 4374 hours at the end of engineering development (ED). The necessary reliability growth rate in order to achieve these values is 0.268.

The VEHICULAR subsystem (Figure 4) has an instantaneous starting MTBF of 1030 hours after 100 hours of growth testing, and achieves an instantaneous MTBF of 3840 hours at the end of AD, and 4130 hours at the end of ED; the required reliability growth rate is 0.274.

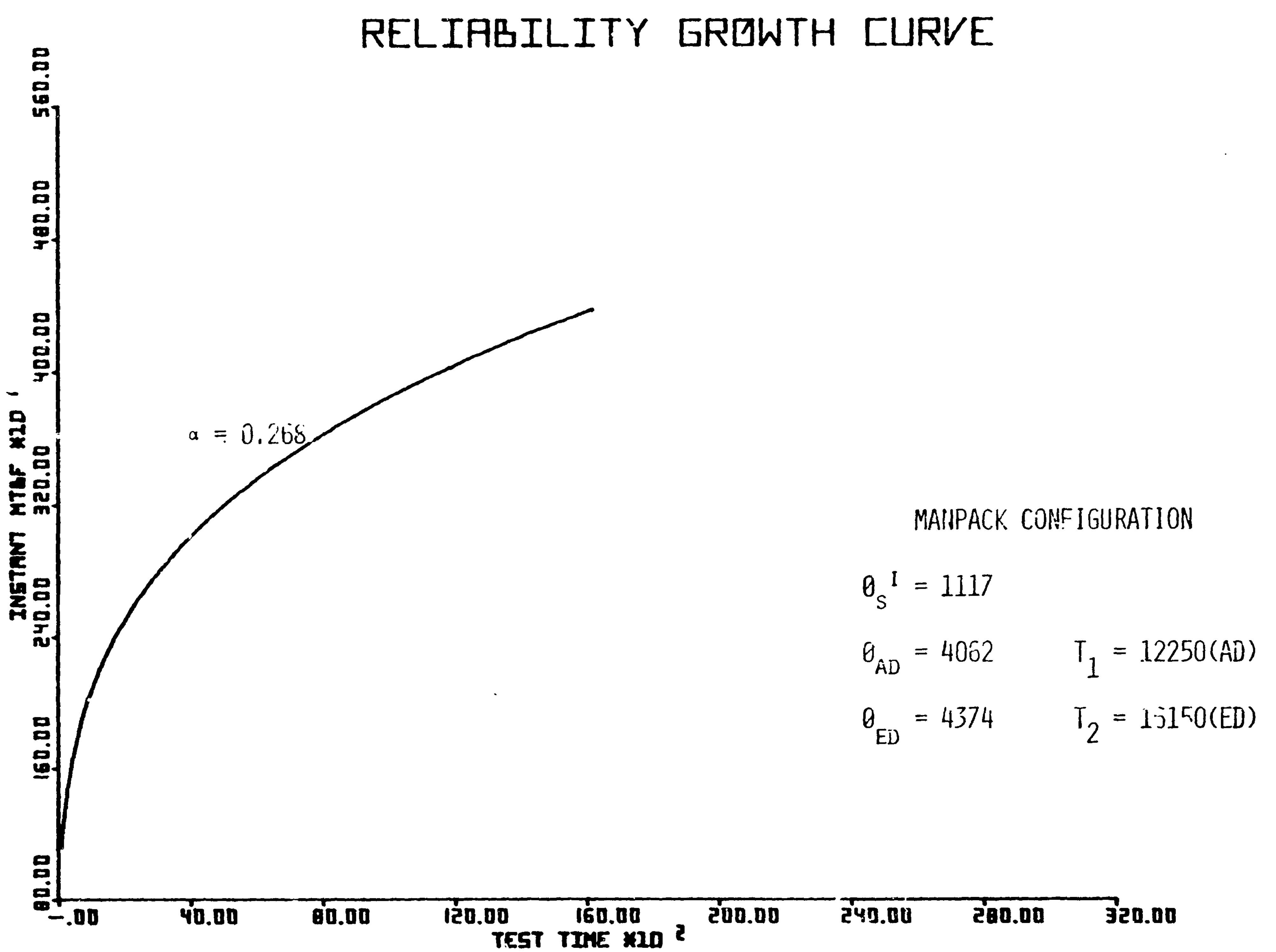


Figure 3. Plot of Manpack Reliability Growth through the end of Engineering Development

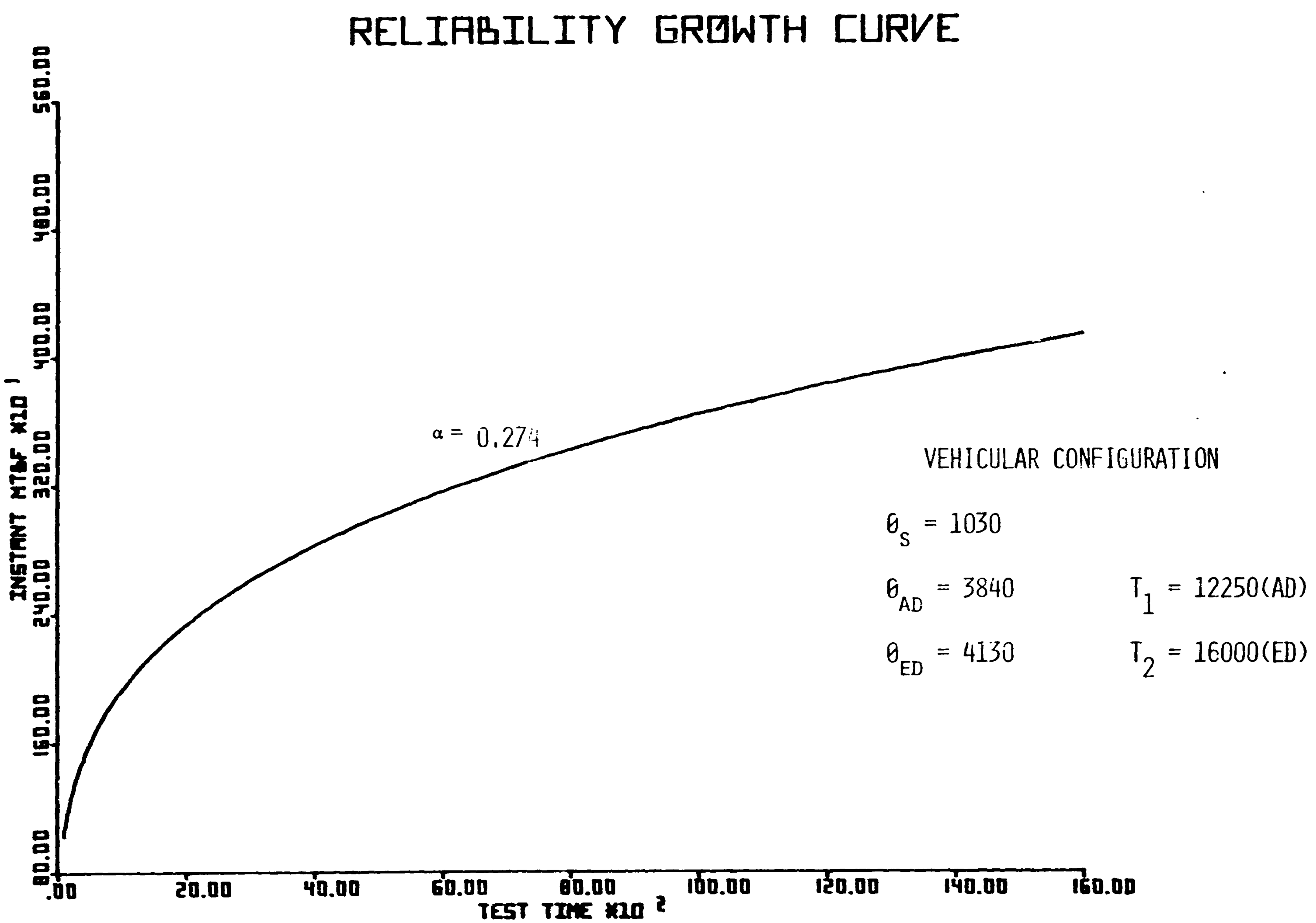


Figure 4. Plot of Vehicular Reliability Growth through the end of Engineering Development

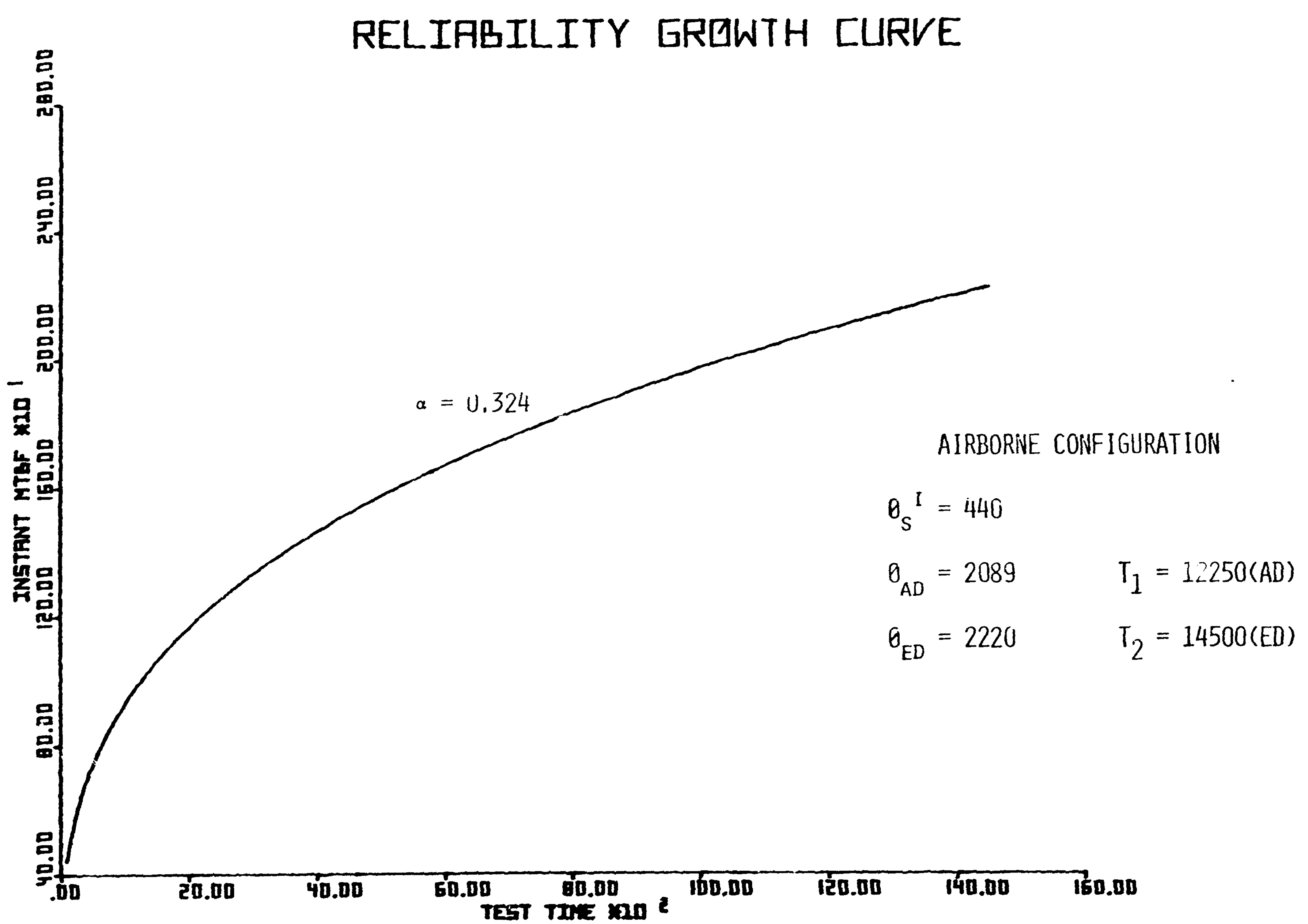


Figure 5. Plot of Airborne Reliability Growth through the end of Engineering Development

The AIRBORNE Subsystem (Figure 5) has an instantaneous starting MTBF of 440 hours after 100 hours of growth testing, and achieves an instantaneous MTBF of 2089 hours at the end of AD, and 2220 hours at the end of ED; the required reliability growth rate for the Airborne Subsystem is 0.324.

The reliability growth test times were calculated assuming 350 hours of usable test time each month, and an optimistic estimate of five available months before OT-I is performed, and seven test units available for growth testing. Since it is the cumulative equipment test time that is of interest, one could obtain the same cumulative test time before OT-I, having nine test samples and only 272 test hours for each of the five months.

Obviously, other combinations of test sample size and monthly testing could yield the same result.

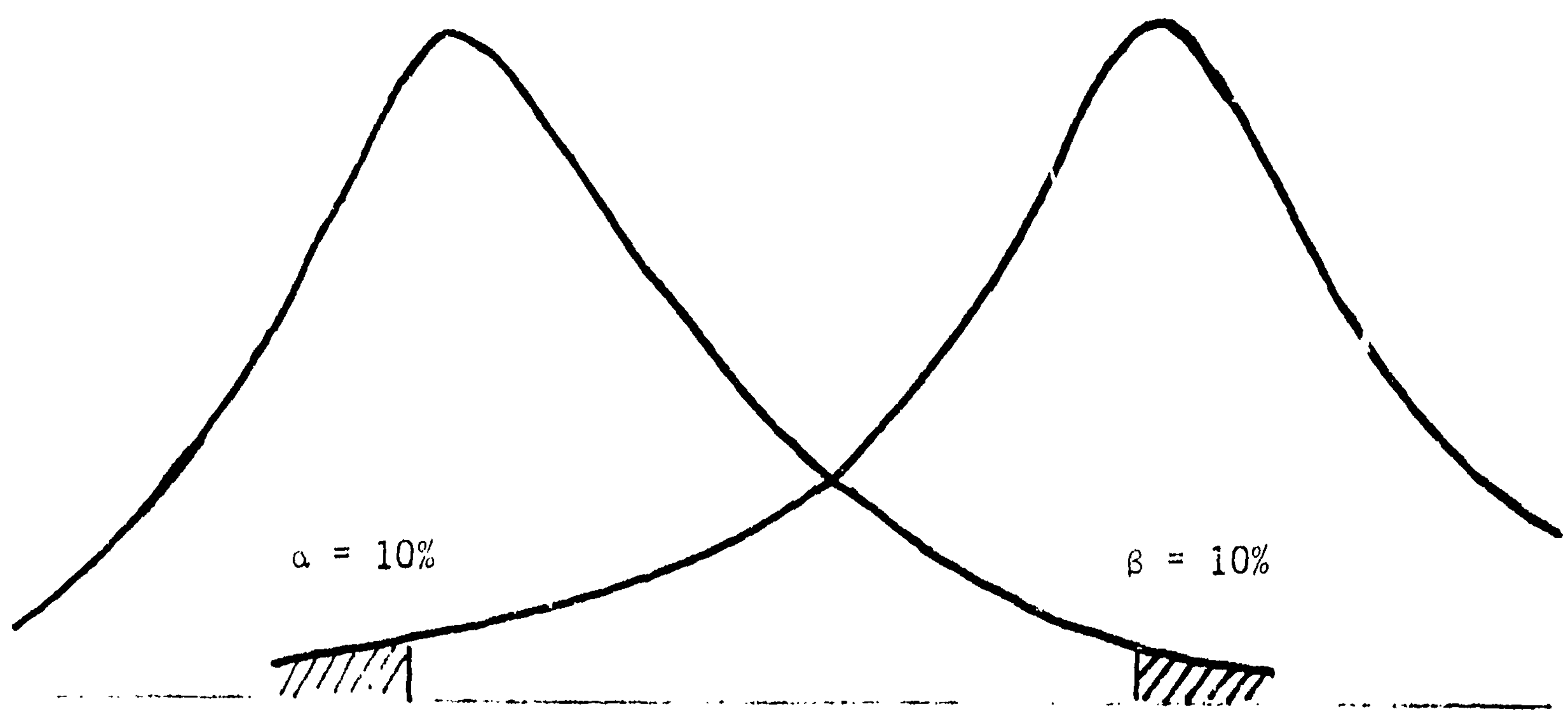
The reliability growth curves shown in Figures 3 through 5 are plots of the instantaneous MTBF versus test time, thus they disregard the effects of prior assignable cause failures. The cumulative MTBF at any point during the reliability growth test accounts for prior assignable cause failures and is calculated by multiplying the instantaneous MTBF by $(1-\alpha)$, where α is the reliability growth rate.

The growth rate required to meet these goals by the end of advanced development are realistic. Under the Duane model growth rates, alpha values, between 0.1 and 0.5 are reasonable. Note, however, that the cost of imposing a reliability growth program increases significantly with an increasing growth rate. This is seen by comparing the cost of the reliability growth programs for each of the cases considered for the Airborne Subsystem. With a growth rate of 0.252, for example, the reliability growth cost was $233 thousand, versus $1.193 million for a growth rate of 0.382.

The reliability growth curves do not reach the specified values by the end of engineering development (ED) because a certain amount of reliability improvement or "growth" will be experienced during the environmental testing, performance testing, and reliability demonstration and qualification testing. The improvement subsequent to the growth testing is directly dependent upon the reliability test acceptance probability, as well as the possibility of performing corrective design actions as a result of reaching a reject decision during the reliability testing.

DISCUSSION OF CONFIDENCE LEVELS

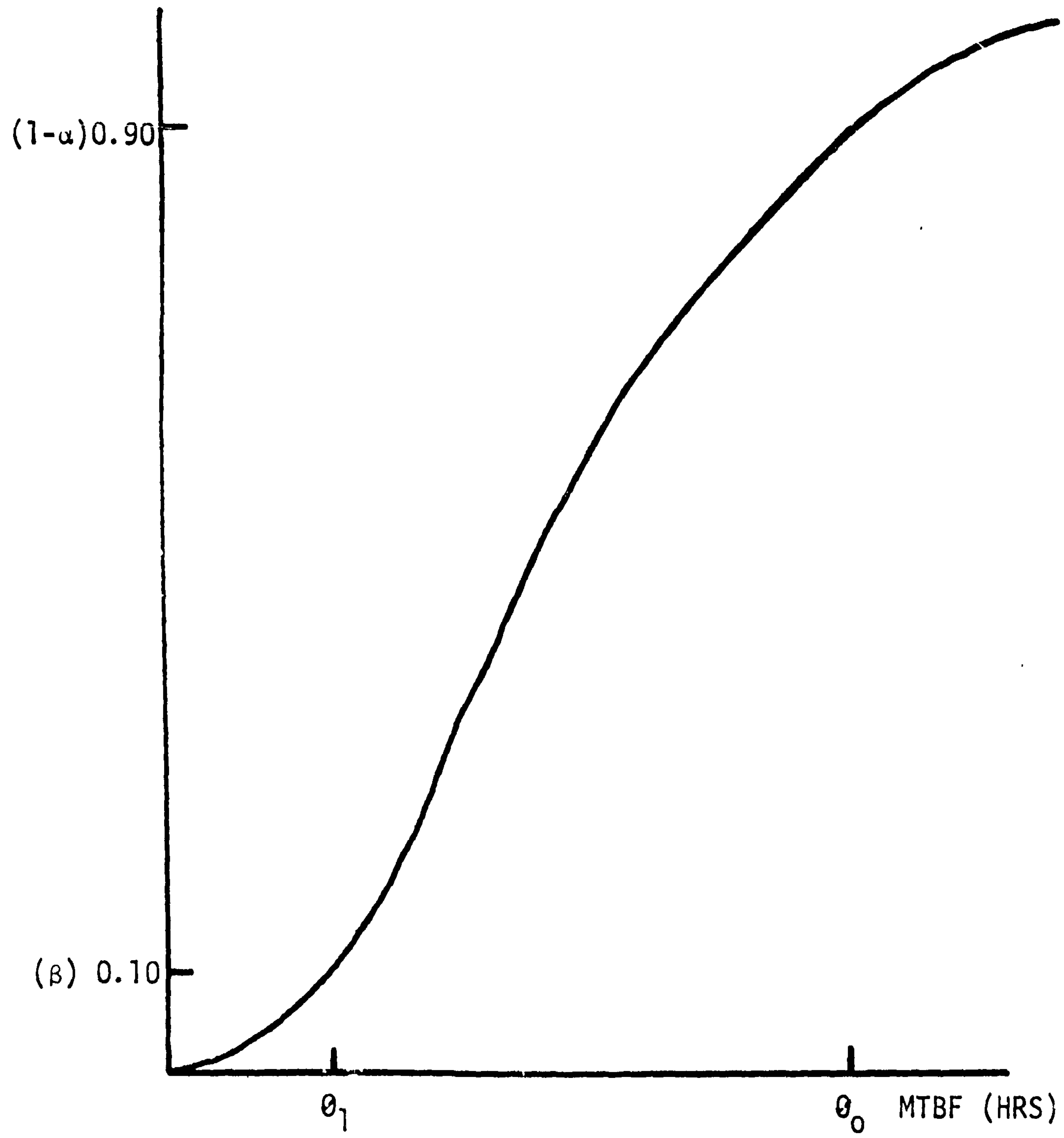
After the equipment's reliability growth testing is finished, it will undergo demonstration testing prior to DT/OT II testing. The values for the specified MTBF were chosen with a "three-to-one" discrimination ratio and an "alpha" risk of 10%. The "alpha" risk is the contractor's risk of rejecting equipment with a true MTBF equal to the specified value (θ_0). Alternatively, the government has a 10% Beta risk of accepting equipment with a true MTBF equal to θ_1. This is equivalent to at least 90% confidence in accepting equipment with an MTBF of θ_1, which is one-third of the specified value, θ_o. Figure 6 is a schematic illustration of the probability distribution associated with each subsystem specification and the corresponding alpha and Beta risks.



	θ_1 (HRS)	θ_o (HRS)
MANPACK	1600	4800
VEHICULAR	1500	4500
AIRBORNE	750	2250

Figure 6. Schematic Illustration of Alpha and Beta Risks.

The statistical confidence in MTBF values below θ_1 is in excess of 90%, so the user's confidence in the respective MAV values exceeds 90%.



MANPACK	1600	4800
VEHICULAR	1500	4500
AIRBORNE	750	2250

Figure 7. Operating Characteristic (OC) Curve.

A plot of the acceptance probability versus MTBF is given in Figure 7. It is sometimes described as an OC (operating characteristic) curve.

The curve shows that the test acceptance probability increases with increasing MTBF, from a lower value of 10% (β value), when the true MTBF equals θ_1, to an upper value of 90% ($1-\alpha$) when the true MTBF equals θ_0.

OPTIMAL RELIABILITY SPECIFICATION VALUES

COSTER was run under four distinct cases for three SINCGARS subsystems: Manpack, Vehicular, and Airborne. The results of the analysis are listed in Tables 2, 3, and 4 for the Manpack, Vehicular, and Airborne subsystems, respectively. Each subsystem was analyzed under discrimination ratios of 2 and 3, where the discrimination ratio is defined as the ratio of θ_0 to θ_1, where θ_0 is the specified inherent reliability (design goal), and θ_1 the value in which the user has 90% confidence. MIL-STD-781B outlines the required test time, sample size, and maximum permissible failures for the demonstration test, qualification test, and production sampling test; the necessary sample size depends upon the inherent MTBF and the available number of test chamber hours.

For the Manpack Subsystem (Table 2), the optimal specified reliability is 4800 hours with 90% confidence in a lower limit of 1600 hours. This value was chosen because it resulted in the minimum annual field support cost per unit of $119. It required a reliability growth program costing $303 Thousand through engineering development (ED), and a growth rate of 0.268.

The Vehicular Subsystem (Table 3) has an optimal specified reliability of 4500 hours, with 90% confidence in a lower limit of 1500 hours. This specified value resulted in a minimum expected annual field support cost per unit of $127. It required a reliability growth program costing $265 Thousand through engineering development (ED), and a growth rate of 0.274.

For the Airborne Subsystem (Table 4), 2250 hours was the value chosen for the specified reliability with 90% confidence in a lower limit of 750 hours. This value was chosen over a specified value of 3000 hours because the reliability growth program required a growth rate of 0.324 costing $572 Thousand which was considered more realistic than the program with a growth rate of 0.382 costing $1.193 Million. This yielded an expected annual field support cost of $328 per unit.

Each of the recommended values for the reliability specification were chosen based on the underlying assumption that the projected reliability growth rate is realistic, and within the capabilities of the contractor. For the AIRBORNE Subsystem, for example, the program requiring a growth rate of 0.382 was eliminated in favor of the program with a growth rate of 0.324.

Table 5 contains the relevant input specification data for each of the optimal programs. The values listed were used in the computerized cost model, COSTER.

Although COSTER was not specifically run on the ECCM device, due to the unavailability of parts count data, the ECCM design goal was specified at 12,000 hours, at the end of ED. Assuming a growth rate roughly comparable to the manpack and vehicular version, the ECCM alone would have achieved 11,140 hours at the end of AD, i.e. after 12,250 hours of growth testing. Table 6 contains the achieved reliability of each configuration alone, and in series with the ECCM device at the end of AD and ED.

TABLE 2

SINCGARS V
MANPACK SUBSYSTEM
(78,000 UNITS, 12 YEAR LIFE)

θ_1 (HRS)	θ_0 (HRS)	RELIABILITY GROWTH RATE, α	RELIABILITY GROWTH COST	TOTAL RELIABILITY PROGRAM COST PER UNIT	ANNUAL FIELD SUPPORT COST PER UNIT
1300	2600	0.155	0.151M	48	203
1600	3200	0.200	0.152M	49	170
1300	3900	0.230	0.234M	51	133
1600	4800 *	0.268	0.303M	52	119

*RECOMMENDED VALUE

TABLE 3

SINGCARS V
VEHICULAR SUBSYSTEM
(110,000 UNITS, 12 YEAR LIFE)

θ_1 (HRS)	θ_o (HRS)	RELIABILITY GROWTH RATE, α	RELIABILITY GROWTH COST	TOTAL RELIABILITY PROGRAM COST PER UNIT	ANNUAL FIELD SUPPORT COST PER UNIT
1250	2500	0.170	0.037M	46	211
1500	3000	0.200	0.139M	47	181
1250	3750	0.240	0.234M	48	137
1500	4500 *	0.274	0.265M	49	127

*RECOMMENDED VALUE

TABLE 4

SINCGARS V
AIRBORNE SUBSYSTEM
(12,000 UNITS, 12 YEAR LIFE)

θ_1 (HRS)	θ_o (HRS)	RELIABILITY GROWTH RATE, α	RELIABILITY GROWTH COST	TOTAL RELIABILITY PROGRAM COST PER UNIT	ANNUAL FIELD SUPPORT COST PER UNIT
750	1500	0.252	0.233M	75	479
1000	2000	0.310	0.510M	100	355
750	2250 *	0.324	0.572M	107	328
1000	3000	0.382	1.193M	179	211

*RECOMMENDED VALUE

TABLE 5 INPUT DATA FOR OPTIMAL PROGRAM

	MANPACK	VEHICULAR	AIRBORNE
θ_0 (HRS)	4800	4500	2250
θ_1 (HRS)	1600	1500	750
MAV (HRS)	1300	1250	750
GROWTH TEST SAMPLE SIZE	7	9	8
DEMONSTRATION TEST TIME (Multiple of θ_0)	3.1	3.1	3.1
DEMONSTRATION TEST SAMPLE SIZE	5	5	5
MAX FAILURES FOR DEMONSTRATION TEST	5	5	5
QUALIFICATION TEST TIME (Multiple of θ_0)	3.1	3.1	3.1
QUALIFICATION TEST SAMPLE SIZE	5	5	5
MAX FAILURES FOR QUALIFICATION TEST	5	5	5
PRODUCTION SAMPLING TEST TIME (Multiple of θ_0)	1.5	1.5	1.5
PRODUCTION SAMPLING TEST SAMPLE SIZE	11	11	11
MAX FAILURES FOR PRODUCTION SAMPLING TEST	2	2	2
CONTRACT SIZE (UNITS)	78000	110000	12000
TOTAL NUMBER OF PRODUCTION SAMPLING TESTS	195	216	120
DEMONSTRATION TEST COST PER CHAMBER HOUR ($)	60	60	60
QUALIFICATION TEST COST PER CHAMBER HOUR ($)	60	60	60

TABLE 5 (CONTINUED)

	MANPACK	VEHICULAR	AIRBORNE
PRODUCTION SAMPLING TEST COST PER CHAMBER HOUR ($)	45	45	45
BURNIN TEST COST PER CHAMBER HOUR ($)	25	25	25
EQUIPMENT USAGE LIFE (YEARS)	12	12	12
DAILY USAGE (HRS/DAY)	3	3	3
WEEKLY USAGE (DAYS/WEEK)	7	7	7
AVERAGE FIELD REPAIR COST ($)	600	600	800

TABLE 6 ESTIMATES OF MTBF FOR EACH SUBSYSTEM WITH AND WITHOUT ECCM CAPABILITY

	ALONE		WITH ECCM	
	θ_{AD}	θ_{ED}	θ_{AD}	θ_{ED}
MANPACK	4062	4374	2976	3205
VEHICULAR	3840	4130	2855	3072
AIRBORNE	2089	2220	1759	1873

BEST OPERATIONAL CAPABILITY (BOC) VALUES FOP SINCGARS-V

The best operational capability (BOC) value for reliability is defined as that level of reliability which is estimated to be technically feasible for the stated time frame within reasonable cost constraints and is in consonance with the best operational capability for which a realistic need exists. Although not specifically stated, it is apparent that the value selected for the BOC should be at least equal to the value selected for the specified value. Based on these criteria, the following estimates of conservative upper limits were established as being greater than the specified value provided by the COSTER computer analysis but believed attainable with reasonable risk based on contractor predictions for the AN/URC-78 radios of approximately 9000 hours and expected technological advances. The values have been adjusted to reflect the expected impact on reliability of various environments and variations in system complexity. The value of 3500 hours for the Aircraft Subsystem is considered to be very conservative but was tempered by a point estimate MTBF of about 3200 hours during over 30,000 hours of contractor testing on the AN/ARC-114.

BOC VALUES

Manpack Subsystem BOC - 5500 hours MTBF

Vehicular Subsystem BOC - 5000 hours MTBF

Aircraft Subsystem BOC - 3500 hours MTBF

The COMSEC BOC has been set at 10,000 hours or more for usage in the ground environment. This value is based upon contractor predictions for the VANDAL of 20,000+ hours.

The Electronic Counter Counter Measures capability (ECCM) has a BOC of 15,000 hours. This is based on general state-of-the-art ECCM techniques, and a specific contractor study on one of the AN/URC-78 contracts. They found that for a slow frequency hopping ECCM device, the predicted MTBF would justify a 15,000 hour MTBF as an attainable goal.

ROC FAILURE DEFINITION: AN ASSESSMENT

The ROC failure definition relating to "inability to provide intelligible communications" is deemed to be too subjective for meaningful scoring criteria. The following definition, as incorporated into the SINCGARS-V specification guideline DS-AF-0200C(A), is as follows:

"A failure is defined as any malfunction which causes or may cause:

a. Cessation of operation.
b. Serious damage to the system by continued operation.

c. Serious personnel safety hazard.
d. Degradation of performance capabilities below those specified in the contractor's specification. Failures which occur in GFE shall be recorded but shall not be counted in calculation of θ_1."

This definition, to be used for each SINCGARS-V subystem, is determined to be more meaningful than the ROC definition. Amplifications of this definition are provided in the Coordinated Test Plan CTP-I for use in government testing. This expanded failure definition is still being coordinated at this time.

RISK ASSESSMENT

Considering current and projected state-of-the-art, the reliability goals stated for SINCGARS-V are attainable with a medium to low risk under an intensive reliability program. The risk would be considerably increased as a result of inadequate management of the reliability program on the part of the contractor or the government.

ACKNOWLEDGEMENTS

The author wishes to thank Ms. Grace Marseglia and Mr. George Neeman for their assistance in running the computer programs necessary to generate Tables 2, 3, and 4 and Figure 2, 3, and 4. Special thanks are also due to Mr. George Goodley and Mr. Fred Wilson for preparing the specification inputs (Appendix I).

REFERENCES

1. Duane, J.T. "Learning Curve Approach to Reliability Monitoring", IEEE Transaction on Aerospace, Vol. 2, No. 2, 1964.

2. Selby, J.D., and Miller, S.G., "Reliability Planning and Management - RPM", Symposium for Reliability and Maintainability Technology for Mechanical Systems, 1972.

3. Solomond, J.P., Marseglia, G.A., Cost Optimizing System to Evaluate Reliability, Proceedings, 1977 Annual Reliability and Maintainability Symposium, Philadelphia, PA.

APPENDIX I

SPECIFICATION INPUTS FOR SINCGARS-V SERIES

3.7 Reliability goals.

3.7.1 Manpack subsystem. The manpack subsystem, including security and ECCM capabilities, shall be tested as a system. The goal for the end of this contract is that the contractor can demonstrate an instantaneous MTBF (θ_i) for the system, less security and ECCM, of 4060 hours or greater when the system is tested under the conditions prescribed by paragraph 4.7.12. The design goal for the system, less security and ECCM capabilities, is a specified mission MTBF (θ_o) of 4800 hours. The contractor may provide, as an option, other MTBF goals, with their associated reliability programs, justified on the basis of life cycle costs.

3.7.2 Vehicular subsystem (long range). The long-range vehicular subsystem, including security and ECCM, shall be tested as a system. The goal for the end of this contract is that the contractor can demonstrate an instantaneous MTBF (θ_i) for the system, less security and ECCM, of 3840 hours or greater, when the system is tested under the conditions prescribed by paragraph 4.7.12. The design goal for the system, less security, ECCM and additional receive-only capabilities, is a specified mission MTBF (θ_o) of 4500 hours. The contractor may provide, as an option, other MTBF goals, with their associated reliability programs, justified on the basis of life cycle costs.

3.7.2.1 Additional receive-only capability. The additional receive-only capability shall be tested as part of the long-range vehicular subsystem. The goal for the end of this contract is that the contractor can demonstrate an instantaneous MTBF (Θ_i) of 3840 hours or greater when this capability is tested under the conditions prescribed by paragraph 4.7.12. The design goal for this capability, less COMSEC, is a specified mission MTBF (Θ_o) of 4500 hours. The contractor may provide, as an option, other MTBF goals, with their associated reliability programs, justified on the basis of life cycle costs.

3.7.2.2 ECCM module. The ECCM module shall be tested as part of all the SINCGARS-V subsystems. The goal for the end of this contract is that the contractor can demonstrate an instantaneous MTBF (Θ_i) of 11,140 hours or greater, when the module is tested under the conditions prescribed by paragraph 4.7.12. The design goal for this module is a specified mission MTBF (Θ_o) of 12,000 hours. The contractor may provide, as an option, other MTBF goals, with their associated reliability programs, justified on the basis of life cycle costs.

3.7.3 Aircraft subsystem. The aircraft subsystem, including security and ECCM capabilities, shall be tested as a system. The goal for the end of this contract is that the contractor can demonstrate an instantaneous MTBF (Θ_i) for the system, less security and ECCM, of 2090 hours or greater, when the equipment is tested under the conditions prescribed by paragraph 4.7.13. The design goal for the system, less security and ECCM capabilities, is a specified mission MTBF (Θ_o) of 2250 hours. The contractor may provide, as an option, other MTBF goals, with their associated reliability programs, justified on the basis of life cycle costs.

4.7 Reliability.

4.7.1 The following guidance for the conduct of reliability testing is provided as a basis for the development of the proposal. Based on research by the US Army Electronics Command these test environments are considered to be the most cost effective laboratory simulations of actual field conditions. Alternate proposals by the bidder will be considered on the basis of supporting information provided with the proposal.

4.7.2 Reliability test. The reliability test shall be conducted in a test-fix-test-fix manner. That is, the equipment is to be tested until a failure occurs. Upon the occurrence of a failure the contractor shall perform an analysis to determine the failure cause. Any corrective action shall be fully documented. Any design change, modification, or replacement shall be applied in like manner to all equipment under test at the earliest possible moment after verification of the proposed change and to all equipment before delivery. The absence of one or more equipments will not affect the ability to continue the test. For reliability test purposes the following paragraphs of MIL-STD-781B shall apply: 5.1.4, 5.2.3.3, 5.4.2, 5.4.2.1, 5.4.2.3, 5.5.1, 5.5.2, 5.5.3, 5.6, 5.8, 5.9, 5.10, 5.10.1, 5.10.2, 5.10.3, 5.10.4, and 5.10.5. In addition to these paragraphs the following shall also apply.

4.7.3 Thermal survey. A thermal survey shall be made of the equipment to be tested under the temperature cycling and duty cycle of the test environments described prior to the initiation of testing for the identification of the component of greatest thermal inertia and the establishment of the time temperature relationship between it and the chamber air. These relationships shall be used for determining equipment thermal stabilization during the test. Temperature stabilization takes place when the temperature of the point of maximum thermal inertia is within 2°C of the test level temperature or its rate of change is less than 2°C/hour. The techniques and results of the thermal survey shall be described, plotted, submitted to and approved by the procuring activity prior to the initiation of testing. Temperatures of the heating-cooling air shall be recorded continuously during both survey and testing. The equipment thermal survey need be made only once for each identical equipment type. A separate thermal survey shall be performed for both the ground and airborne environment described.

4.7.4 Test facilities. Test facilities shall be capable of maintaining the conditions specified for the applicable environments and of measuring equipment characteristics to the specified accuracy for the duration of the test. Test facilities shall be subject to the approval of the Government.

4.7.5 Test chambers. Test chambers shall be capable of maintaining the ambient and forced air temperatures as specified with an accuracy of $\pm 2°C$ during the test. Chamber and forced air temperature shall be monitored continuously. Thermostats shall be installed to interrupt the programming motor used in automatic control of the environmental cycle until maximum and minimum air temperature requirements are satisfied.

4.7.6 Vibration. The vibration shall be as specified in the test environments. If the equipment is designed to be used with shock isolators, it shall be so mounted during the reliability test. If it is designed to be hard mounted, no shock isolators shall be used during the reliability test. When the equipment being tested contains circuit boards or cards, vibration shall be normal to the plane of the majority of the cards; otherwise, the direction of vibration is not critical. The vibration equipment shall be checked for proper operation each 24 hours of operation and the vibration transducers shall be on and monitored continuously during vibration.

4.7.7 Measurements. As required, equipment performance parameters shall be measured at least daily. Measurements shall be taken at various points throughout the temperature cycling (i.e., high temperature, low temperature, midrange temperature). The number of times measurements are taken at the various points should be approximately equal. If a failure is detected, it shall be presumed to have occurred immediately after the last successful measurement of the same parameter.

4.7.8 Manpack subsystem. The manpack subsystem shall be tested as a system under the conditions prescribed by paragraph 4.7.12. A minimum sample size of seven (7) shall be used. The total combined "on" time shall be 12,250 hours. Proper instrumentation shall be provided to identify failures.

4.7.9 Vehicular subsystem. The vehicular subsystem shall be tested as a system under the conditions prescribed by paragraph 4.7.12. A minimum sample size of seven (7) shall be used. The total combined "on" time shall be 12,250 hours. Proper instrumentation shall be provided to identify failures.

4.7.9.1 Additional receive-only capability. The separate receive-only capability shall be tested as part of the long-range vehicular subsystem under the conditions prescribed by paragraph 4.7.12. A minimum sample size of three (3) shall be used.

4.7.9.2 ECCM module. The ECCM module shall be tested as part of all the SINCGARS-V subsystems.

4.7.10 Aircraft subsystem. The aircraft subsystem shall be tested as a system under the conditions prescribed by paragraph 4.7.13. A minimum sample size of seven (7) shall be used. The total combined "on" time shall be 12,250 hours. Proper instrumentation shall be provided to identify failures.

4.7.11 Failure definition. A failure is defined as any malfunction which causes or may cause:

a. Cessation of operation.

b. Serious damage to the system by continued operation.

c. Serious personnel safety hazard.

d. Degradation of performance capabilities below those specified in the contractor's specification. Failures which occur in GFE shall be recorded but shall not be counted in the calculation of θ_i.

Detailed failure definitions are in the CTP-I, dated 1 December 1976.

4.7.12 Terrestrial environment simulation.

4.7.12.1 Temperature cycling. The procedure outlined below shall be used throughout the reliability test.

Temperature Cycling Procedure:

Step 1 With the equipment OFF, lower the chamber temperature to -57°C ±2°C.

Step 2 Maintain the chamber temperature at -57°C ±2°C for a period of one (1) hour.

Step 3 Raise the chamber temperature to -32°C ±2°C at a rate of temperature change not less than 5°C/minute. When the chamber temperature reaches -32°C ±2°C turn the equipment ON.

Step 4 Maintain the chamber temperature at -32°C ±2°C for a period of 2-1/2 hours.

Step 5 Raise the chamber temperature to 55°C ±2°C at a rate of temperature change not less than 5°C/ minute.

Step 6 Maintain the chamber temperature at 55°C ±2°C for a period of 3 hours.

Step 7 Turn the equipment OFF and raise the chamber temperature to 71°C ±2°C.

Step 8 Maintain the chamber temperature at 71°C ±2°C for a period of one (1) hour.

Step 9 Lower the chamber temperature to 55°C ±2°C and turn the equipment ON.

Step 10 With the equipment ON, maintain the chamber temperature at 55°C ±2°C for a period of 2-1/2 hours.

Step 11 Lower the chamber temperature to -32°C ±2°C at a rate of temperature change not less than 5°C/ minute.

Step 12 Maintain the chamber temperature at -32°C ±2°C for a period of 3 hours.

Step 13 Turn the equipment OFF and lower the chamber temperature to -57°C ±2°C.

Repeat Steps 2 through 13 throughout the reliability test. Completion of Steps 2 through 13 shall herein be referred to as one temperature cycle. If the thermal survey indicates that the soak periods called for in Steps 2, 4, 6, 8, 10, and 12 are insufficient for equipment thermal stabilization, these soak periods shall be modified so that stabilization is obtained.

4.7.12.2 Voltage spike. Once every 200 hours of equipment ON time an electrical stress shall be applied to the equipment. This stress shall be applied in accordance with MIL-STD-461, Method CS06. The point in the temperature cycle at which this stress is introduced shall vary during the reliability test to include both application at low temperature extremes and high temperature extremes.

4.7.12.3 Humidity. Once per temperature cycle humidity shall be introduced into the test chamber which will cause condensation or frosting. The introduction of humidity shall be at different times and temperatures of the cycle such that the temperature at which condensation or frosting occurs varies during the test. Also, the number of times condensation and frosting is present during the test shall be approximately equal.

4.7.12.4 Duty cycle. During the equipment's ON time the duty cycle shall be 90% receive and 10% transmit, with the exception of the separate receive-only capability, which shall have a duty cycle of 100% receive.

4.7.12.5 Voltage cycling. The input voltage shall be maintained at one hundred ten percent (110%) nominal for one temperature cycle. At the completion of that temperature cycle the input voltage shall be maintained at the nominal value for one temperature cycle and then maintained at ninety percent (90%) nominal for the third temperature cycle. This cycling procedure is to be repeated continuously throughout the reliability test.

4.7.12.6 Vibration. Once per hour of equipment ON time the equipment shall be subjected to a 15 minute vibration cycle. This vibration shall be at 1.0 inch $\pm$10% double amplitude between 5 Hz $\pm$1/2 Hz and 6.3 Hz $\pm$1/2 Hz and 2g $\pm$10% between 6.3 Hz $\pm$1/2 Hz and 500 H. $\pm$2%. The sweep rate shall be logarithmic and shall take 15 minutes to go from 5 Hz to 500 Hz to 5 Hz (one complete vibration cycle).

4.7.13 Aircraft environment simulation.

4.7.13.1 Temperature cycling. The procedure outlined below shall be used throughout the reliability test.

Temperature cycling procedure:

Step 1 With the equipment OFF, lower the chamber temperature to -62°C ±2°C.

Step 2 Maintain the chamber temperature at -62°C ±2°C for a period of one (1) hour.

Step 3 Raise the chamber temperature to -54°C ±2°C at a rate of temperature change not less than 5°C/min. When the chamber temperature reaches -54°C ±2°C turn the equipment ON.

Step 4 Maintain the chamber temperature at -54°C ±2°C for a period of 1-1/2 hours.

Step 5 Raise the chamber temperature to 55°C ±2°C at a rate of temperature change not less than 5°C/min.

Step 6 Maintain the chamber temperature at 55°C ±2°C for a period of two (2) hours.

Step 7 Turn the equipment OFF and raise the chamber temperature to 80°C ±2°C.

Step 8 Maintain the chamber temperature at 80°C for a period of one (1) hour.

Step 9 Lower the chamber temperature to 55°C ±2°C and turn the equipment ON.

Step 10 With the equipment ON, maintain the chamber temperature at 55°C ±2°C for a period of 1-1/2 hours.

Step 11 Lower the chamber temperature to -54°C ±2°C at a rate of temperature change no less than 5°C/min.

Step 12 Maintain the chamber temperature at -54°C ±2°C for a period of two (2) hours.

Step 13 Turn the equipment OFF and lower the chamber temperature to -62°C ±2°C.

Repeat Steps 2 through 13 throughout the reliability test. Completion of Steps 2 through 13 shall herein be referred to as one temperature cycle. If the thermal survey indicates that the soak period called for in Steps 2, 4, 6, 8, 10 and 12 are insufficient for equipment thermal stabilization these soak periods shall be modified so that stabilization is obtained.

4.7.13.2 Voltage spike. Once every 200 hours of equipment ON time an electrical stress shall be applied to the equipment. This stress shall be applied in accordance with MIL-STD-461, Method CS06. The point in the temperature cycle at which this stress is introduced shall vary during the reliability test to include both application at low temperature extremes and high temperature extremes.

4.7.13.3 Humidity. Once per temperature cycle humidity shall be introduced into the test chamber which will cause condensation or frosting. The introduction of humidity shall be at different times and temperatures of the cycle such that the temperature at which condensation or frosting occurs varies during the test. Also, the number of times condensation and frosting is present during the test shall be approximately equal.

4.7.13.4 Duty cycle. During the equipment's ON time the duty cycle shall be 90% receive and 10% transmit.

4.7.13.5 Voltage cycling. The input voltage shall be maintained at one-hundred-ten percent (110%) for one temperature cycle. At the completion of that temperature cycle the input voltage shall be maintained at the nominal value for one temperature cycle and then maintained at ninety percent (90%) nominal for the third temperature cycle. This cycling procedure is to be repeated continuously throughout the reliability test.

4.7.13.6 Vibration. Once per hour of equipment ON time the equipment shall be subjected to a 15 minute vibration cycle. This vibration shall be at .05 inch $\pm$10% double amplitude between 5 Hz $\pm$1/2 Hz and 24.5 Hz $\pm$1/2 Hz and 1.5g $\pm$10% between 24.5 Hz $\pm$1/2 Hz and 500 Hz $\pm$2%. The sweep rate shall be logarithmic and shall take 15 minutes to go from 5 Hz to 500 Hz to 5 Hz (one complete vibration cycle).

4.7.14 Modes of operation. The equipment under test shall be exercised in its various modes of operation, in accordance with an apportionment which will be determined by the Test Integration Working Group (TIWG) and documented in the Coordinated Test Program I (CTPI).

4.8 Electromagnetic interference tests.

4.8.1 Bonds and grounds. The 2.5 milliohm bonding requirement of 3.8.3 shall be verified prior to any other EMI test. The bonding measurements shall be made using a Shallcross Model 670A (or equivalent) milliohm meter. The bonding measurements shall be made at the points listed below (as a minimum, as applicable) and recorded for inclusion in the EMI/EMC test report:

a. Between each connector shell and the equipment chassis (at least once in each quadrant).

b. Between each lid (or panel) and the equipment chassis (measured from half-way between each mating screw (or fastener) on the lid to the opposite point on the chassis).

c. Bonding of the ground lead of power filters to the equipment ground plane shall be verified to be 2.5 milliohms (maximum).

4.8.2 Emission and susceptibility. The equipment shall be tested for compliance with the requirements of 3.8.1. Test setups and test procedures shall conform to the measurement techniques of MIL-STD-462, Notice 3, as implemented by contractor supplied, Government approved, EMI test plan. A susceptibility failure shall include false equipment operation, as well as out-of-tolerance operational requirements specified herein.

DISTRIBUTION LIST FOR SINCGARS-V REPORT

	No. Copies
Project Manager SINCGARS ATTN: DRCPM-GARS Fort Monmouth, NJ 07703	5
Commander US Army Test and Evaluation Command ATTN: DRSTE-EL Aberdeen Proving Ground, MD 21005	2
Commander US Army Security Agency ATTN: IATEL-T IATEL-SEC Arlington Hall Station, VA 22212	3
Director National Security Agency ATTN: S-72, R-121 Fort Meade, MD 20755	3
Commander US Army Training and Doctrine Command ATTN: ATCD-SC ATCD-TM Fort Monroe, VA 23651	2
Director US Army Materiel Systems Analysis Activity ATTN: DRXSY-CC DRXSY-RN Aberdeen Proving Ground, MD 21005	2
Commander US Army Operational Test Evaluation Agency ATTN: CSTE-TM-C3 5600 Columbia Pike Falls Church, VA 22041	4
Commander US Army Logistics Evaluation Agency New Cumberland Army Depot ATTN: DALO-LEI New Cumberland, PA 17070	1
Commander US Marine Corps Development Center ATTN: CCC Division Quantico, VA 22134	1
Chief Department of Air Force ATTN: RDQLM Washington, DC 20350	1
Chief of Naval Operations Department of Navy ATTN: OP-098 Washington, DC 20350	2
Commandant US Army Signal School ATTN: ATSN-CD-TE Fort Gordon, GA 20905	4
Commander US Army Electronics Command ATTN: DRSEL-CE Fort Monmouth, NJ 07703	2
Commander US Army Aviation Systems Command ATTN: DRCAV-EVA St. Louis, MO 63166	1
Director US Army Human Engineering Lab ATTN: DRXHE-HE Aberdeen Proving Ground, MD 21005	2

	No. Copies
Commander US Army Logistics Center ATTN: ATCL-MC Fort Lee, VA 23801	1
Commander US Army Maintenance Mgt Center ATTN: DRXMD-EA DRXMD-TR Lexington, KY 40511	2
Commander US Army Tank Automotive Command ATTN: DRSTA-REA Warren, MI 48090	1
Chief US Army Communications Security Logistics Agency ATTN: DRSEL-CCM-PM Fort Huachuca, AZ 85613	1
Project Manager Firefinder ATTN: DRCPM-FF-PA Fort Monmouth, NJ 07703	1
Headquarters Department of the Army ATTN: DAMA-CSC-CM DAMO-TCE Washington, DC 20310	 2 1
Commander US Army Electronic Proving Ground ATTN: STEEP-MT-G Fort Huachuca, AZ 85613	2
Office of the Under Secretary of the Army(OR) ATTN: Dr. Willard Washington, DC 20350	1
Commander US Army Materiel Development and Readiness Command ATTN: DRCQA 5001 Eisenhower Avenue Alexandria, VA 22304	1

	No. Copies
Commandant US Marine Corps ATTN: Code RDD-27 Washington, DC 20380	1
Commander US Army Training Systems Analysis Agency ATTN: ATAA-TCC White Sands Missile Range, NM 88002	1
Project Manager US Army Tactical Data System ATTN: DRCPM-TDS-SE Fort Monmouth, NJ 07703	1
Project Manager Multi-Service Communications System ATTN: DRCPM-MSCS-TM Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-WL-V Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-NL-RN Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-NL-RY Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-SA Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-TL-P DRSEL-TL-I Fort Monmouth, NJ 07703	2

	No. Copies
Director TRI-TAC ATTN: PP-RT Fort Monmouth, NJ 07703	2
Commander US Army Electronics Command ATTN: DRSEL-VL-S Fort Monmouth, NJ 07703	1
Project Manager Navigation/Control Systems ATTN: DRCPM-NC Fort Monmouth, NJ 07703	1
Commander US Army Electronics Command ATTN: DRSEL-RD-I Fort Monmouth, NJ 07703	1
Deputy Director Test and Evaluation Office DDR&E ATTN: Asst Dir (TAC Sys T&E) Washington, DC 20301	1
Project Manager Remotely Monitored Battlefield Sensor System ATTN: DRCPM-RBS-L Fort Monmouth, NJ 07703	1
Chief of Naval Operations ATTN: OP-941C Washington, DC 20350	1
President US Army Airborne Communications & Electronics Board ATTN: ATXA-BD-CE Fort Bragg, NC 28307	1
US Army Infantry School ATTN: ATZB-CD Fort Benning, GA 31905	1

	No. Copies
US Army Field Artillery School ATTN: ATSF-CD-TS Fort Sill, OK 73503	1
US Army Armor School ATTN: ATZK-CD Fort Knox, KY 40121	1
US Army Aviation School ATTN: ATZQ-D-MS Fort Benning, GA 31905	1
Commander US Army Electronics Command ATTN: DRSEL-PA Fort Monmouth, NJ 07703	2
Commander US Army Combined Arms Center Development Agency ATTN: ATCA-COC Fort Leavenworth, KS 66027	1
Project Manager XM-1 Tank System ATTN: DRCPM-GCM-1 28150 Dequindre Warren, MI 48092	1
Defense Documentation Center Cameron Station Alexandria, VA 22314	12
Commander US Army Electronics Command ATTN: DRSEL-MS-TI Fort Monmouth, NJ 07703	2